Damage Mapping and Mechanism Discovery in Silicon Films and Wafers

Christopher Muhlstein[1] and Eric A. Stach[2]
[1]School of Materials Science and Engineering, Georgia Institute of Technology,
[2]Center for Functional Nanomaterials, Brookhaven National Laboratory

For decades silicon-based electronics, microelectromechanical systems (MEMS), and photovoltaics were thought to be immune to damage accumulation and subcritical crack growth mechanisms such as environmentally-assisted (stress corrosion) cracking and fatigue. Silicon's purported immunity was a byproduct of its linear elastic constitutive behavior (i.e., no plastic deformation occurs at temperatures below its ductile to brittle transition of 565°C) and its rapidly forming, passivating oxide layer. However, the combination of small size and high loading frequencies in silicon-based MEMS revealed that silicon can, in fact, accumulate damage and exhibit delayed failures at stresses well below its fracture strength. In this presentation we will explore these damage accumulation mechanisms and how they were revealed using the unique electron microscopy tools at national lab user facilities. We will then illustrate their relevance to the viability of photovoltaic power plant installations and the critical role that synchrotron X-ray beamlines can play in quantitative mapping of damage in photovoltaic modules